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NATIVE SNAILS OF THE GENUS *BOTHRIEMBRYON* IN KING'S PARK, PERTH

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INTRODUCTION

Iredale's (1939) review of the Western Australian land snails reveals that two species of *Bothriembryon* occur in or adjacent to the Perth area. These are *Bothriembryon bulla* (Menke, 1843; type locality Darling Range), and *Bothriembryon indutus* (Menke, 1843; type locality Darling Range and Mount Eliza). The original material was collected by Ludwig Preiss, a German naturalist, who worked in Western Australia from 1838 to 1842.

Dead shells of these snails can be found in numbers after the periodical controlled burns which are a feature of forestry practice in King's Park. One would expect, therefore, that local naturalists would be aware of their presence. However no field studies have been done on the life histories, status, or inter-species relationships within the area adjacent to Perth.

Difficulties associated with naming specimens may have deterred would-be workers in the field. Iredale *(op. cit.)* lists over forty species for South-Western Australia. Within the genus one can clearly define species groups, and, within such groups one is forced to depend on locality rather than morphology for determining specific names. Populations are also found which show a great range of colour and shape of shell. It is apparent that this is a taxonomically difficult group and if one defines species in biological rather than morphological terms, i.e. as populations rather than as structurally different animals, one may, within this genus, have an opportunity of studying speciation processes.

One of the authors has collected live specimens (i.e. coloured shells containing the animal) over the geographic range of the genus from Sharks Bay to South Australia. As a preliminary to a broader approach to the species relationships of the whole genus, work of an observational nature has proceeded in King's Park and this is recorded here.

DISTRIBUTION OF THE SNAILS IN KING'S PARK

Extensive collecting in the Park shows that *Bothriembryon indutus* occurs on the cliffs facing the Swan River, and that

Bothriembryon bulla occurs on the high land away from the cliffs and the river. Closer examination of the area away from the river reveals the presence of another form having a black body and a strikingly striped shell. The three forms are shown in Fig. 1.

There is no doubt that the coloration of the shell and the secretive nature of the animal make it difficult to collect an adequate number of live animals for mapping distributions. However, by collecting during the first autumn rains, when animals

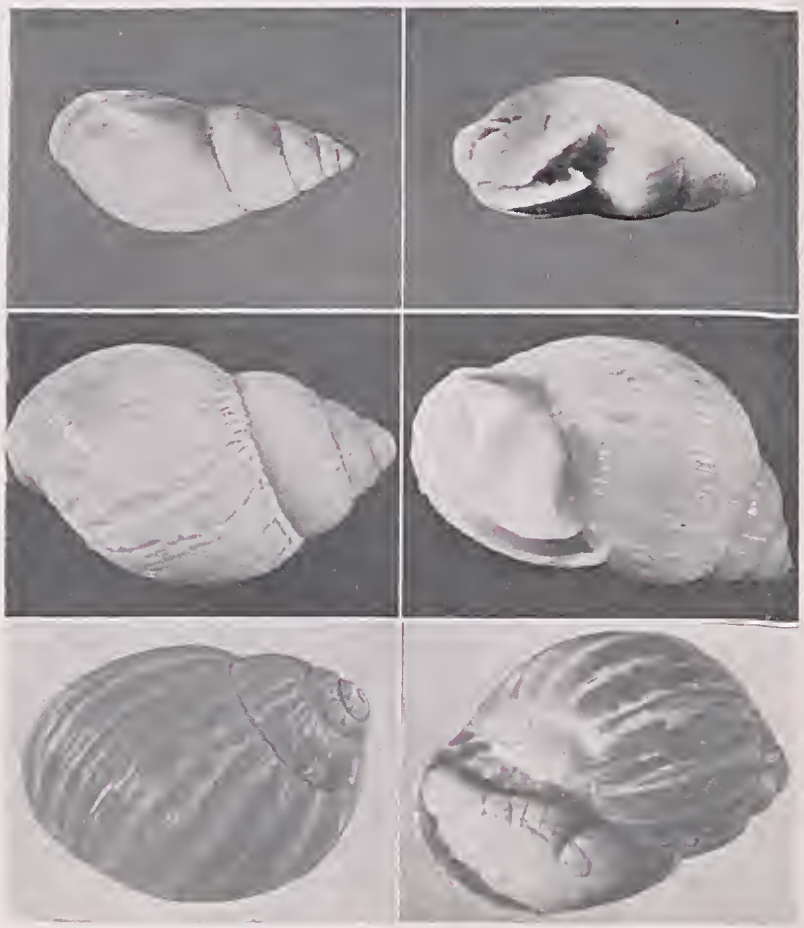

Fig. 1.—The three forms of *Bothriembryon* found in King's Park. Top row. *Bothriembryon indutus* x 1; left, dorsal view; right, ventral view showing foot. Centre row. *B. bulla,* typical form, x 2; left, dorsal view; right, ventral view. Bottom row. *B. bulla,* melanic form, x 2.5; left, dorsal view; right, ventral view; note the dark foot and pigmented and striped shell.

—Photos E. Walsh.

appear above the leaf litter in the day time, or by turning over litter and soil under shrubs to a depth of several inches, one may obtain specimens of the black form and *B. bulla*. Such methods applied to the search for *B. indutus* have yielded only a small fraction of the number collected of the other species. Perhaps this indicates a real difference in the density of the populations, but this is difficult to reconcile with the commonness of dead shells. Shells of *B. indutus* are relatively uniform in colour and shape. It is worth noting that in extensive collecting outside the Park, e.g. on the Darling Scarp, *B. indutus* is widespread though common only in small, apparently favourable sites. Here *B. indutus* prefers to aestivate under stones on scree slopes. Distribution of the three forms based on all collections made within King's Park is shown in Fig. 2. From this it is clear that there are three apparently distinct populations in the area under discussion. This statement is not entirely true as four black-bodied individuals were found in 1953 within the area marked as *B. bulla*, at the sites shown on Fig. 2. With these exceptions in mind the populations can be typified as in Table I.

TABLE 1.—CHARACTERISTICS OF POPULATIONS OF BOTHRIEMBRYON IN KING'S PARK.

Character.	Population 1 Bothriembryon indutus	Population 2 Bothriembryon bulla	Population 3 melanic form
Body	Pale yellow	Pale yellow	black
Shell			
Height. Max. observed*	38 mm.	25 mm.	18 mm.
Width. Max. observed	19 mm.	16 mm.	14 mm.
Height:Width. Max. observed	2.00	1.56	1.28
No. of whorls	5½	5	4½
Colour, alive	Red-brown or greenish-yellow.	Straw, faintly striped.	Yellow stripes.
Dead shell	Opaque. Very well calcified.	Opaque. Well calcified.	Thin translucent brown. Poorly calcified.

There is no chance of confusing the long narrow-spired *indutus* with either of the other populations but population 3 differs from *bulla* only in body colour, and in having a more globose and less calcified shell. Even so, a striped black-bodied form occurs among the typical *bulla* and although distributions (see map), are so discrete, one has no hesitation in stating that these are only polymorphs of the one species. However, with the very unequal distribution in the small area of the Park, one is immediately conscious of the subtlety of causal factors in the distribution observed.

We consider that the peculiar distribution of the two forms of *B. bulla* is best interpreted as an interaction of the animals' natural history with environmental factors such as the nature of the vegetation, soil, forestry management, and predation, and these factors are considered in the following sections.

*A statistical analysis of this genus is to be published elsewhere.

NATURAL HISTORY OBSERVATIONS

(a) VAGILITY.

The following observations relate to the period from the winter of 1951 to 1953. Because the area occupied by the black-bodied population was readily available to one of us it was chosen for observation. Thirty animals were marked by sticking a numbered tag on to the body whorl of the shell, and covering it with a clear nail polish lacquer. Numbers attached in this way showed no sign of deterioration after several months of field conditions. None of these tagged specimens were collected in 1953.

By constantly observing marked animals over a period of nine consecutive days (from June 27 to July 6, 1951) it was found that the maximum distance covered in 24 hours was 10 feet, while over the same period, the average daily movement was 3 feet. Movement was not strictly random but seemed to favour clumps of *Scaevola paludosa*. Other observations indicated that this plant was particularly favoured by the melanic snail early in the morning. None of the leaves of this plant showed signs of having been eaten by snails, but since the leaves are hairy and hold water in the hairs, it is suspected that it is the water that the snails find attractive. *Scaevola* also forms a good leaf litter and may thus provide cover during the day. When kept under observation in the laboratory, snails will feed on the dead leaves of this plant.

With the marked animals an attempt was made to estimate population density in this area by a technique of mark and recapture. However this was unsuccessful due mainly to vagaries of weather to which snails reacted, so that only on dull wet days without wind, could one expect to obtain a reasonable number of animals on the surface. The typical *B. bulla* is even more difficult to census than the day-moving melanic form, since it seems to feed very rarely in daylight, and even when feeding is commonly deep in vegetation, or if on the sand surface only under relatively dense vegetation up to four inches in height. This preference for cover while feeding and during daylight is reflected in the preference for the dense *Jacksonia gracilis* and makes any census method extremely difficult and inaccurate.

Because of the difficulty of making an accurate census it seems undesirable to guess at the relative abundance of the two polymorphs in the Tuart Association but it seems probable that the melanic form may vary from between 5 per cent. and 10 per cent. of the total population. On the other hand, the melanic form in the Jarrah-Banksia Association is easily visible and here even though the under sides of shrubs and other sites have been carefully searched a pale-bodied form has never been seen.

Under dry conditions snails were observed to bury themselves in the sand beneath leaf litter or under shrubs and the typical

B. bulla frequented *Jacksonia gracilis*. This burrowing was done with the foot while the animal slowly revolved. *B. bulla* generally burrowed only deep enough to cover the shell to the top of the spire. Indications are that under summer drought conditions the typical *B. bulla* does not bury as deeply as the melanic phase. This may be due to behaviour differences or characteristics of the sand (see later), or both. Under summer conditions, buried animals seal the aperture with an epiphragm.

(b) REPRODUCTION

Copulation proceeds as follows: One snail crawls on to the body whorl of another. The lower animal comes halfway out of its shell, the eyes and tentacles being withdrawn and the body twisted so that the genital aperture faces upwards. The upper animal comes out to its full extent but with eyes and tentacles withdrawn. The body is twisted so that the genitals face downwards. During copulation there is a mutual exchange of sperm.

The male organs are white and thread-like, and protrude, in copulation, from the right hand side of the body just behind the eye stalks. In the melanic form the penis is about 7.5 mm. long when extruded.

Copulation takes more than 20 minutes and during this time large quantities of mucus are secreted. During 1951 copulation was observed in the melanic population on the following days: May 6 and 7, June 10, 20, 24, 27 and 28 and July 5. Observations on marked specimens showed that individuals copulated more than once in a season. At no time were the melanic forms seen to copulate with the typical *B. bulla*, but this may be due to infrequency of this polymorph in the typical *bulla* area and the fact that most of the observations on the melanic were central and not peripheral to the melanic area.

In the first season of investigations no egg laying was observed, but on August 16, 1953, eggs were found in King's Park in two shallow closely adjacent holes, $\frac{1}{2}$ in. in diameter by $\frac{3}{4}$ to 1 in. deep. In the sand at the bottom of these two holes 22 eggs were collected (from observations made outside of the Park the range per individual hole is from 11 to 14 eggs). Eggs are nearly spherical, 3 mm. in diameter, opaque white, and with white granules in the outer part. Small snails can be seen within the egg membranes after 30-35 days at a temperature of 60 deg. F. At hatching, the embryo shell has $1\frac{1}{2}$-$1\frac{3}{4}$ whorls.

DESCRIPTION OF AREA AND GEOLOGY

King's Park is native woodland entirely surrounded on the north and west by built up areas and on the south and east by the Swan River. The total area is approximately 1,000 acres. The shape and topography is given in Fig. 2. The rocks of the area are consolidated calcareous dune rock, Pleistocene aeolianite, originally composed of comminuted shell fragments, echinoderm spines and plates, some tests of foraminifera, and rounded and

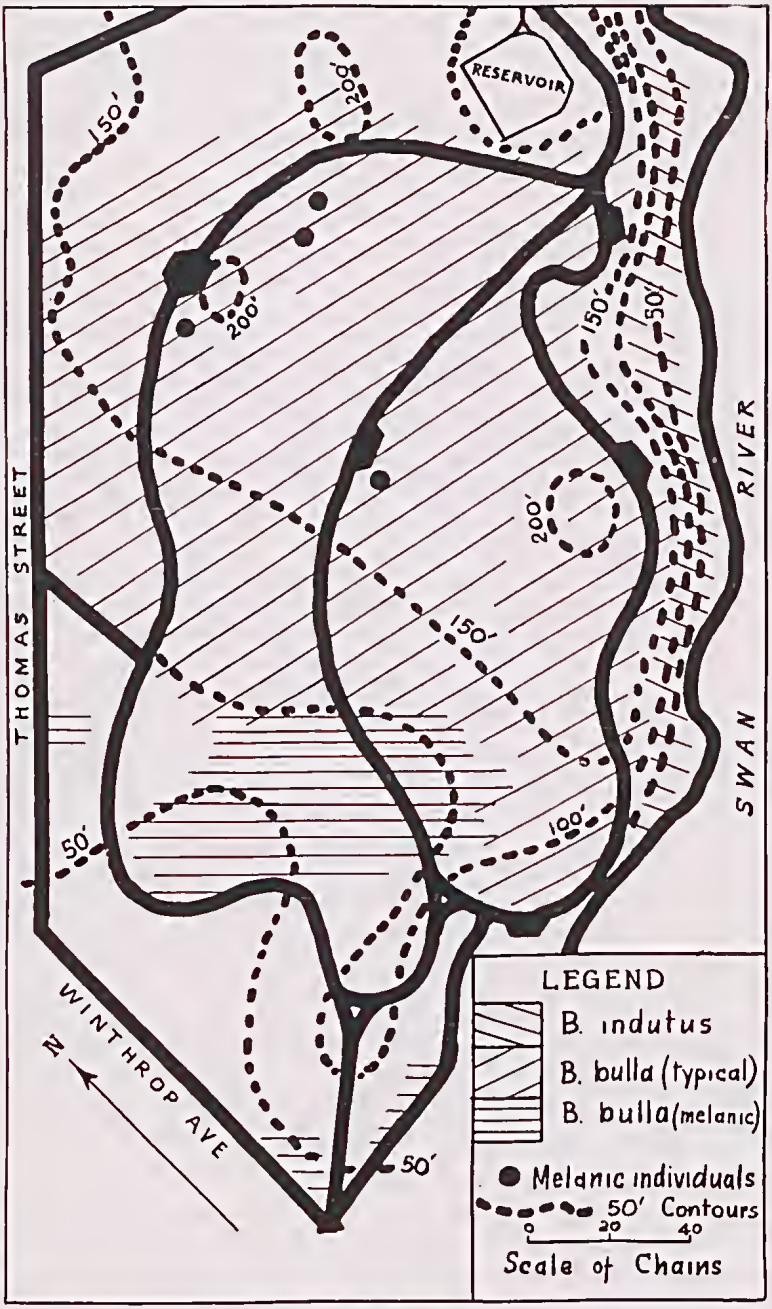

Fig.. 2.—Map of King's Park, showing roads, contours and the distribution of the snails of the genus *Bothriembryon*.

Fig. 3.—Map of King's Park, showing distribution of sands of equal particle size; plotted by using median diameters of sands in millimetres and lines of equal size extrapolated for values of 0.50, 0.45, and 0.40 mm. The hatched area shows the main occurrence of sands with a particle size exceeding 0.50 mm.

frosted quartz grains. This rock outcrops on the steep cliffs facing the Swan River. Over aeolianite a deep siliceous soil has developed, which is leached for about 12 inches and passes down into a yellow zone where the quartz grains have a thin coating of limonite (iron oxide). This zone is of variable thickness, exceeding ten feet in places and rests on a thin, dense travertine layer of reprecipitated calcium carbonate developed on the surface of the indurated dune rock below which it still retains its original bedding.

Sieve analyses of 40 samples of the surface sand from selected sites enabled lines of equal particle size to be drawn (using median diameters in millimetres, see Fig. 3). Inspection of Figs. 2 and 3 reveals that the coarser grain sizes of 0.50 mm. and over are favoured by the melanic population. The coarser particles are nearly all below the 100 foot contour line, i.e. at the base of the old dune. Vegetation boundaries also seem to be related to this change (see later). Many factors, e.g. pore space, moisture holding capacity, permeability, and rate of drying may control the presence of characteristic snails and vegetation. The voids ratio of the coarser sands will be greater than the fine sands, which means that they will hold more water when saturated but have greater permeability and a faster drying rate which will cause more rapid loss of moisture. Finally, coarser sands reach a lower equilibrium moisture content during the dry months. From this it is apparent that the resistance to desiccation of an aestivating snail on this soil would have to be greater than on a finer soil which holds less water when saturated but also loses it more slowly. To test this hypothesis sites have been selected at which winter and summer moisture contents will be measured, along with a parallel laboratory programme to compare the resistances to desiccation of the three populations of snails. As already suggested the coarser sand may allow the melanic form to burrow deeper.

VEGETATION

Miss A. M. Baird, of the Botany Department, University of W.A., has kindly made available a complete list of the flora in the Park. The flora is classified into two associations; one dominated by *Banksia* spp. and Jarrah *(Eucalyptus marginata)*, and the other by Tuart *(E. gomphocephala)*. These correspond respectively with the area below the 100 foot contour having coarser sand and that above the 100 foot contour with fine sand as already discussed. Tuart areas are known to have limestone beneath the surface at no great depth while non-Tuart areas have no limestone beneath the surface.

With regard to the formations Miss Baird writes (pers. comm.) of the Tuart Association: "Trees widely spaced (most in very poor condition), a very much more open formation than the Jarrah-Banksia Association. The dense uniform undergrowth

of mixed shrubs, predominantly *Daviesia* sp., *Hibbertia, Oxylobium,* characteristic of the Jarrah-Banksia, is absent.

"Immediately round the base and under the canopy of big Tuart trees are *Pelargonium drummondi, Trichinium,* and sometimes *Clematis.* Other common shrubs typical of the Tuart Association are *Scaevola holoscricca, Jacksonia graeilis,* and *Grevillea vestita.* The undergrowth in general is more herbaceous, much softer, and more mesophytic than in the Jarrah Association."

EFFECT OF BURNING THE AREA

Large areas of Western Australia are burnt each year by fires and Forestry Department practice is to have controlled burns every 3-4 years or as soon as leaf litter and other growth will carry fire. This control measure is to prevent the accumulation of litter which increases the risk of uncontrolled fires during the dry summer. Such fires are a feature of the Park management and with good conditions for the burn, little damage is done to standing timber. All herbs and, depending on the intensity of the fire, a good number of the shrubs are burnt. However it is noticeable that *Jacksonia gracilis,* a recumbent shrub lying on the ground and often many feet in diameter, and which is almost restricted to the Tuart Association, is only scorched around the edges but does not burn to the centre. Other mesophytic plants frequently resist the effect of light burns. On the other hand it is noticeable that the Jarrah-Banksia Association has no shrubs which resist fire as does *Jacksonia gracilis.* Thus when an area is devastated by fire the Tuart Association shows many scattered plants of *Jacksonia* which are unburnt and have acted as refuges while the Jarrah-Banksia area shows nothing surviving except the well grown timber. Further, since *B. bulla* apparently prefers the *Jaeksonia* and *Pelargonium* which do not burn readily, this species seems to be favourably situated, not only in having a refuge in which to avoid the fire but also a ready source of leaf litter on which to feed in the ensuing winter. The ground under Jarrah-Banksia Association is black and bare, there are no refuges, and the first soft leaf litter to form will be from *Scaevola* which like other shrubs will regrow from the root stock. In this association and shortly after a burn there is usually a fall of scorched 'leaves' of *Casuarina* sp. which are common in this community. These pale brown needles lie heavily over the ash and charcoal of the fire.

No predators have been recorded as eating *Bothriembryon* in the Park but the Western Magpie *(Gymnorhina dorsalis)* is common and is a ground feeder. K. G. Buller has observed the Squeaker (*Strepera versicolor),* a bird closely related to the magpie, and also a ground feeder, which was feeding on *Bothriembryon balteolus* at the Phillips River. The method of feeding is given in detail by Buller (see this number, p. 70).

CONCLUSIONS

From the observations made on marked animals it is quite apparent that an animal with the observed degree of vagility of *B. bulla* could easily move and mate over the distanees in the Park, and thus produee a homogenous population. It is elear that the two forms are selected so that the movement which does take place does not result in a uniform population. Differenees in the vegetation which must be related to geological differenecs are eo-extensive with the distribution of the snails, but this does not explain the distribution until it is appreeiated how the two assoeiations differ when subjected to burning. The Tuart Assoeiation has refuges in *Jacksonia gracilis* while the Jarrah-Banksia Assoeiation has no refuges but the ground is soon covered with fallen *Casuarina* needles. Snails in this latter assoeiation, feeding at the surfaee as soon as winter rains eome, and long before the soil has an adequate plant cover, are then preyed upon by some ground-frequenting bird whieh in this loeality is likely to be the Western Magpie. As the birds are proteeted in the Park this postulated predation cannot be eheeked, but Buller's observations on a elosely related speeies lend support to this eontention. The predation must be effieient and highly seleetive in order to produce the reeorded homogeneity in the melanie population, where all animals seen were blaek-bodied and had shells showing a high degree of cryptie coloration. The colour pattern is quite obviously related to the blaek soil and brown *Casuarina* litter of the population area.

As the blaek forms in the typieal *bulla* area have quite well developed shells, the thinness of the shell in the melanie population is probably related to the absenee of ealeium in the heavily leached soil on whieh it is found.

The behaviour and depth to whieh snails burrow is possibly a complex interaetion between behavioural differences and ease of burrowing in the eoarse sand. Whatever the interaeting faetors, it is certain that the melanie form with its deeper burrow ean avoid the seorehing of the fires and ean thus eseape in the same way as the typieal *Bothriembryon bulla* whieh appears to have a ready refuge in *Jacksonia*.

A knowledge of egg laying will obviously give an opportunity of eheeking on the segregation of the genes for melanism and shell pattern and will also give an indieation of the juvenile shells of any area, i.e. before the suggested predation has seleeted for the appropriate type. Future work in this area will centre on population eounts and eonfirmation of different behaviour patterns in the polymorphs eoupled with eonfirmation of the suggested predation.

SUMMARY

Two species of the genus *Bothriembryon* occur in King's Park, viz. *Bothriembryon indutus* and *B. bulla*. The latter is polymorphic with two forms:— one white-bodied with yellow shell and another black-bodied with striped shell. The melanic polymorph is rare in the Tuart Association where the yellow form is common; but in the Banksia-Jarrah Association only the melanic polymorph is found. *B. indutus* shows little variation in form and occurs only on the cliffs facing the Swan River. Observations on the natural history of *B. bulla* and the melanic form are reported. The distribution of the soils of the Park are given and the two plant associations present are discussed in relation to the edaphic factors. Cover is present in the Tuart Association but is absent in the Jarrah-Banksia Association after fires. It is suggested that the distribution of the typical *B. bulla* (yellow form) and the melanic form, in the Tuart Association and Jarrah-Banksia Association respectively, is due to predation by the Western Magpie *(Gymnorhina dorsalis)* in relation to relative destruction of cover by fire.

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AMANITAS FROM KING'S PARK, PERTH

By J. GENTILLI, Nedlands.

(Continued from Page 34)

Amanita loricata sp. nov.

The type specimen (Fig. 5) was found at the end of June, a few years ago, some hundred yards from the south-western corner of King's Park. At the end of May 1953 another specimen, partly damaged but clearly recognizable, was found in the north-western section of the Park.

Cap 5-6 cm. in diameter, slightly concave except at the edge, of a uniform biscuit colour, covered with patches of small pointed biscuity warts, and with an outer ring of thick raised angular warts, also biscuit in colour.

Gills strongly ventricose, over 1 cm. broad, attenuated outward, rounded towards the stem, adnexed, crowded, white.

Stem 10-12 cm. long, 20-22 mm. thick, subcylindrical, slightly flattened laterally in one specimen, stuffed, with white flakes above and biscuit fibrillose flakes below, and remnants of a superior evanescent cream-white ring. The foot of the stem (seen in the type specimen only) is glandiform, with a distinct furrow which separates it from the stem proper, around the base of which are several rings of fibrils, remnants of the volva.

Spores elliptical to ovate, hyaline singly, white in mass.

This species has a distinct smell of yeast or rising dough, sweetish to faintly sour.